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# LANDING CRAFT AIR CUSHION (LCAC) NAVIGATOR SELECTION SYSTEM: INITIAL MODEL DEVELOPMENT

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# ABSTRACT

The Landing Craft Air Cushion (LCAC) is an amphibious hovercraft that can ride on a cushion of air across land or sea. Its control features are similar to a helicopter, and it is designed to transport weapons, cargo, equipment and combat personnel. In the 1980s, the LCAC community was experiencing a high attrition rate, partially due to the absence of any valid selection mechanisms for crewmembers. The Naval Aerospace Medical Research Laboratory (NAMRL) developed a selection system for the LCAC operators and engineers, and the system was transitioned to the Naval Aerospace Medical Institute, (now the Naval Operational Medicine Institute) in 1992. When similar attrition problems were seen in the navigator community, we were again tasked with developing a selection system in FY 94-95. Concurrent validation of the system was done using 58 LCAC navigators. The preliminary predictive model was generated, and the cut-off score was derived from the sponsor's operational manpower needs. To date, 30 candidates have been screened; 25 have been recommended for training. Thirteen of these candidates have entered training and completed the full 22-week syllabus. Five of the 13 recommended candidates attrited during training, with "failure to handle multitasking" as the main reason sited. The system is still being evaluated to (1) possibly include more multitasking tests, (2) modify the predictive algorithm, and/or (3) raise the cut-off score to further reduce the attrition rates.

## Acknowledgments

# INTRODUCTION

A Landing Craft Air Cushion Vehicle, or LCAC, is one of the most unusual transport vehicles in the world (see Fig. 1). The LCAC is a hovercraft that rides on a cushion of air across land and/or sea. It can reach 70% of the world's coast line, whereas most ships can only reach 30%. The control features of the craft are similar to those of a helicopter, with three axes of rotation: vertical, forward/backward, and side to side. The LCAC was specifically designed to transport weapons, equipment, and combat-ready personnel from ship to shore. In the future, the system's missions may be expanded in the future to include medical evacuations during wartime operations, noncombatant evacuations, and lane clearing during amphibious landings. For personnel delivery and medical evacuations, the LCAC deck is modified to include a Personnel Transport Module (PTM), which is a series of metal boxes that sit in the center of the deck. For lane-clearing operations, the concept is to have the LCAC fire several rounds of explosive off its bow to detonate mines and clear a channel for troop delivery.
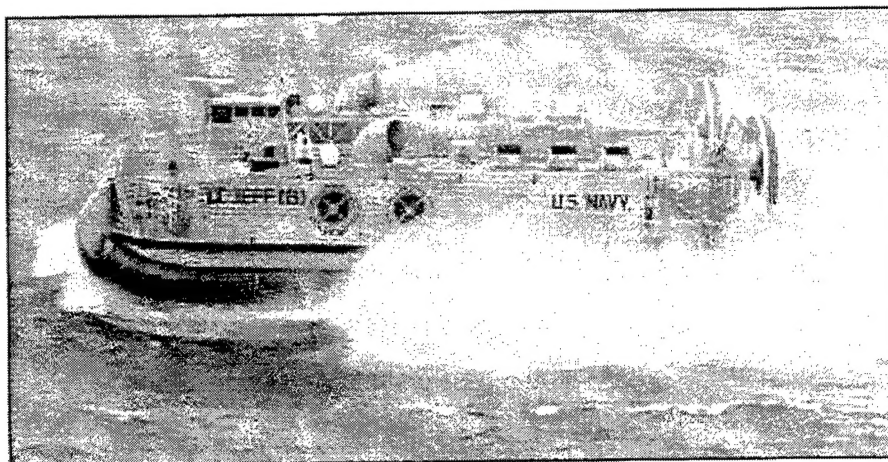


Figure 1. Landing Craft Air Cushion Vehicle.

The LCAC crew consists of five enlisted personnel: loadmaster, deckmaster, craftmaster, engineer, and navigator. The loadmaster and deckmaster are responsible for the load (personnel, tanks, etc.) that is being transported, and they are usually located in the port crew stations during sea operations. The craftmaster, engineer, and navigator are all located in the starboard crew stations. The craftmaster is responsible for the actual control of the LCAC vehicle. The engineer monitors engine performance and limitations and relays the information to the craftmaster. The navigator is responsible for maintaining and monitoring navigation equipment as well as plotting courses and planning for collision avoidance. This information is also relayed to the craftmaster. In addition to these duties, the navigators and the engineers have some external visual scanning responsibilities to further support the craftmaster in control of the craft. The crew communication during actual operations is extensive. Lastly, LCAC navigators are also responsible for maintaining personnel and training logs ashore.

In the mid to late 1980s, the LCAC operator and engineer community were facing a training attiriton rate of 40-60% (Eakin, 1990). Due to these excessive rates, combined with the relative high cost of this training, the Naval Aerospace Medical Research Laboratory (NAMRL) was funded by the Naval Sea Systems Command (NAVSEA) to develop a selection system to reduce this rate. The system was completed, and in 1992 it was transitioned to the Naval Aerospace Medical Institute (now the Naval Operational Medicine Institute, NOMI) (Helton, Nontasak, & Dolgin, 1992). The attrition rate has been reduced to approximately 15% since that time (Robertson & Nontasak, 1996). In the early 1990s a similar problem developed within the navigator community where attrition rates were 40-50%. These high attritions were making it difficult for the LCAC community to meet their deployment needs, and NAMRL was again tasked with rapidly developing a screening system for the navigator position.

1

## METHODS

### SUBJECTS

The original model sample included 58 LCAC navigators from Assault Craft Unit (ACU)-4, Little Creek, Virginia, and ACU-5, Camp Pendleton, California. All navigators included in the original validation of the system had completed the LCAC navigators course and were qualified for the navigator position. The number of operating hours as an actual navigator ranged from 112 to over 3500 h. This group of individuals was used as the concurrent validation sample. Thirty navigators were from ACU-4, and 28 were from ACU-5. The subjects were exclusively male and had achieved the grade of at least a first class petty officer, or chief (E-6 or E-7).

The subjects used for the predictive modeling consisted of enlisted personnel ($n = 30$) who were interested in entering the LCAC navigator training program. They are routinely sent to the Naval Operational Medicine Institute for physical screening for the program. As part of that screening, they are sent to NAMRL for testing on the performance battery described below. All but two subjects were male, and all subjects had achieved a grade of at least a second or first class petty officer (E-5 or E-6). No subjects reported any previous experience as a navigator.

### MATERIALS

### Hardware

All testing was done on an IBM/PC compatible (386/25 MHz) or greater, VGA monitor, joystick, numeric keypad, and headphones. The system setup can be seen in Fig. 2.
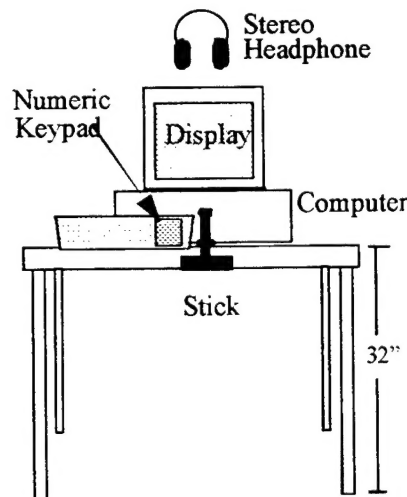


Figure 2. System Setup.

### LCAC Navigator Selection System (LNSS)

Key personnel in the LCAC community were interviewed to identify the skills and abilities necessary to be a successful crew member. Based on these interviews and task rankings, several in-house tests were identified to be included as part of the LNSS (Nontasak, Dolgin, & Griffin, 1989). The test battery consisted of a series of individual and multiple tasks. The subtests were as follows: Pychomotor test/Dichotic Listening Task (DLT), Absolute Difference (AD), Manikin, Time Estimation Task (TET), and a Complex Visual Task (CVT).

The psychomotor test measures eye-hand coordination. A joystick is located directly in front of individuals and moves in all four directions. Individuals are required to maintain crosshairs in the center of the monitor (see Fig. 3) for the duration of the task. A random drift function on the crosshairs forces subjects to make constant adjustments with the joystick to maintain the crosshairs at the centerpoint. The task is performed individually for three 2 minute trials. The tracking error obtained is the cumulative pixel error distance from the center of the screen across multiple trials.



Figure 3. Stick.

The DLT is a listening task in which individuals are required to wear headphones. A string of letters and numbers are presented one at a time via the headphones, however, the information being heard in the left ear is different from that in the right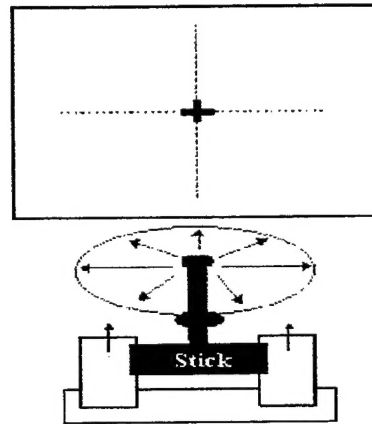 ear (Fig. 4). Using the numeric keypad, individuals respond to only the numbers heard in a particular ear, as designated by the computer. This task is first completed individually for 12 trials, and then done simultaneously with the psychomotor task mentioned above. The subjects are again given a total of a 12 combined trials. The performance measure for the stick task is the logarithm to the base 10 of the tracking error score. The performance measure for the DLT is a cumulative score for the number correct.

| Sequence | Left Ear Stimulus | Right Ear Stimulus |
|---|---|---|
| Trial # | "Test 1" | "Test 1" |
| Attention | "RIGHT" | "RIGHT" |
| Stimuli | "R 8 N S M Y 2 G B 7 F L 6 R L 5" | "Y L 3 S R 4 F Z 9 X F 0 F N 1 L" |
| Pause | | |
| Attention | "LEFT" | "LEFT" |
| Stimuli | "B F 4 3 7 9" | "G L 1 5 6 2" |

Figure 4. Dichotic Listening Task.

The AD task is a cognitive skills test. Single digit numbers are presented one at a time on the screen, and individuals are asked to take the absolute difference between the current number and the previous number on the screen. Inputs are made using the numeric keypad. For example, if the first number on the screen is a 4 and the next number is a 3, then 1 would be entered into the keypad. As soon as that is done, a new number will appear, for example a 6. The difference between the 6, which is the current number and the 3, which was the previous number would be calculated and entered via the keypad. This task is performed for two 2-min trials. Performance is measured as the average number of correct responses minus the number of incorrect responses over the two trials. Reaction times for both responses are also recorded.

The manikin is a spatial apperception or mental rotation task. An image of a sailor is presented on the screen. In one hand he is holding a green circle and the other a red square (Fig. 5). The objective of the task is to determine which hand is holding the red square. The sailor can be in 4 different positions. Rightside up and facing you, rightside up and backwards, upside down and facing you, or upside down and backwards. Responses are made using the keypad and consist of a simple left versus right-hand determination. The test is timed (three 2-min trials), and individuals are told to do as many of the manikin presentations as possible, while maintaining their accuracy. Performance is measured as the number of correct responses minus the number of incorrect responses, as well as the reaction time for each correct and incorrect response.
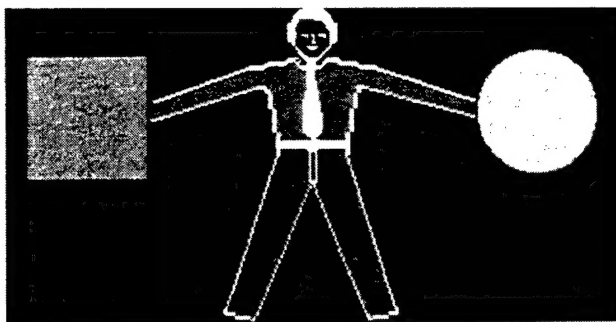


Figure 5. Manikin.

The TET (Fig. 6) is a multitask test that measures time-distance estimation, as well as psychomotor skills. For the TET, individuals are required to perform two tasks. First, they are required to keep a crosshair centered at the bottom of the screen with a left to right motion of a joystick. During this task, at the upper left part of the computer monitor, a horizontally moving target (an airplane) enters the visual field for about 2 to 3 s and then disappears. In the upper right side of the screen is a target zone. From the initial visually observed speed of the target, subjects must determine when the target will be located directly above the target zone. At that point, they must squeeze/fire the trigger button located on the joystick. When they squeeze the trigger button, feedback on their accuracy is given as a number that appears over that target zone. The number reflects the pixel error (distance) from the optimal target zone. A positive number means that they overestimated the speed of the aircraft and fired too soon. Likewise, a negative number means that they underestimated the speed of the aircraft and fired too late. The smaller the number, the closer they came to directly targeting the aircraft. Between trials, the aircraft target can travel at different speeds, however, within trials it maintains the same speed. The number of trials and speeds are consistent between subjects. Subjects receive two 4-min trials. Neither task is presented in isolation. Performance is measured as the average of the logarithm to the base 10 of the tracking score and the pixel error from the target.
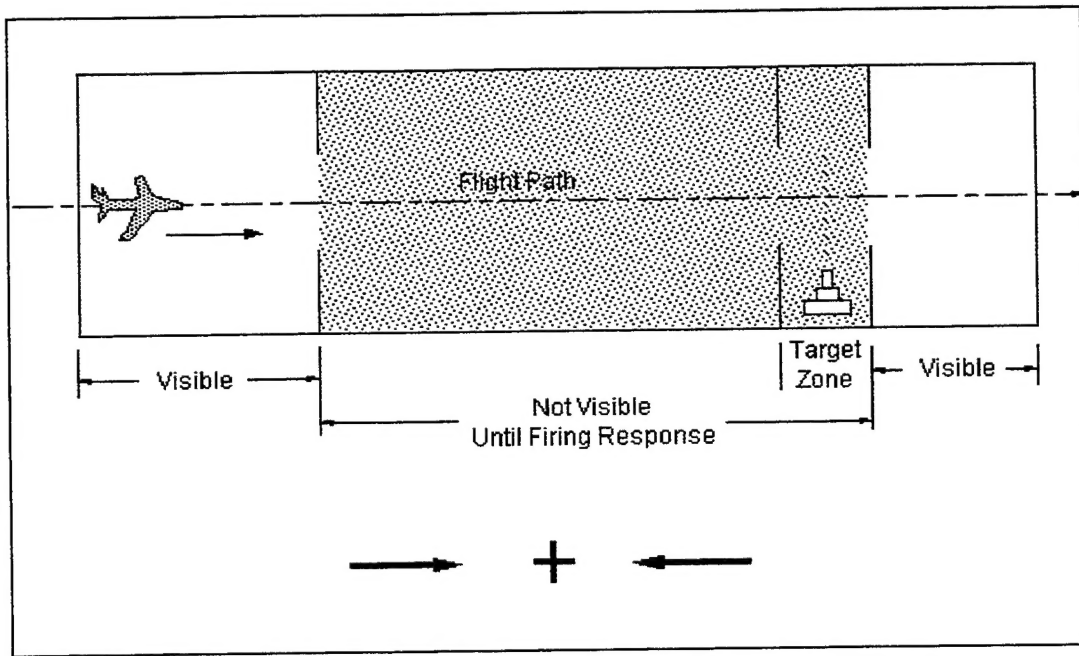
Figure 6. Time Estimation Task.

The last subtest included in this test battery is the CVT, which was originally developed as a selection tool for the navigator position in the naval flight officer community (Morrison, 1988). The system was designed to assess an individual's ability to encode verbal information and manipulate pictorial displays in working memory. Individuals are first presented a test question (Fig. 7). The question's content is related to an image (called the tactical display) that will be presented in the successive screen of the test. An individual reads the question and then prompts the tactical display by pressing the enter key on the keyboard. The display contains a circle with crosshairs and a number of objects of various shapes, sizes, and colors. These objects are located in different quadrant locations and facing various directions (Fig. 8). The goal of the subject is to respond correctly to the initial question given the visual image on the screen. Questions may be true and false or numeric in nature. The subject responds using the keypad. Once a response is made, immediate feedback is given concerning whether answers were correct or not. The subject then must press the enter key again to proceed to the next question. The test contains 60 questions. Subjects are asked to complete all questions as quickly and as accurately as possible. Performance is measured as the number correct and incorrect responses out of the total possible correct. In addition, the time to read the question; and the reaction times for correct and incorrect questions are also recorded.
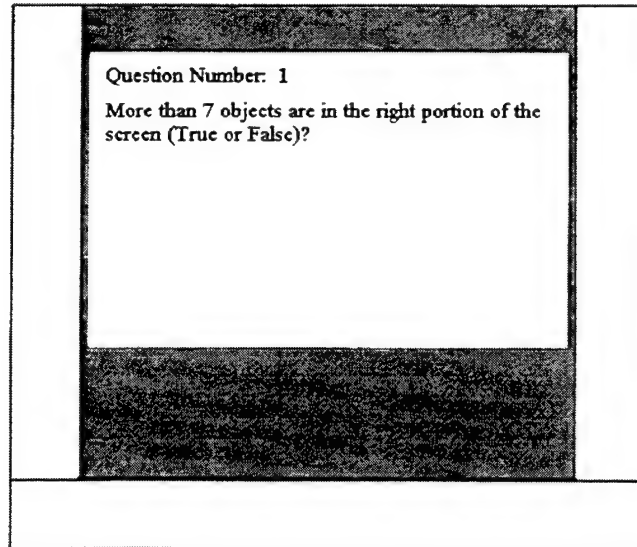
Figure 7. Question Display.
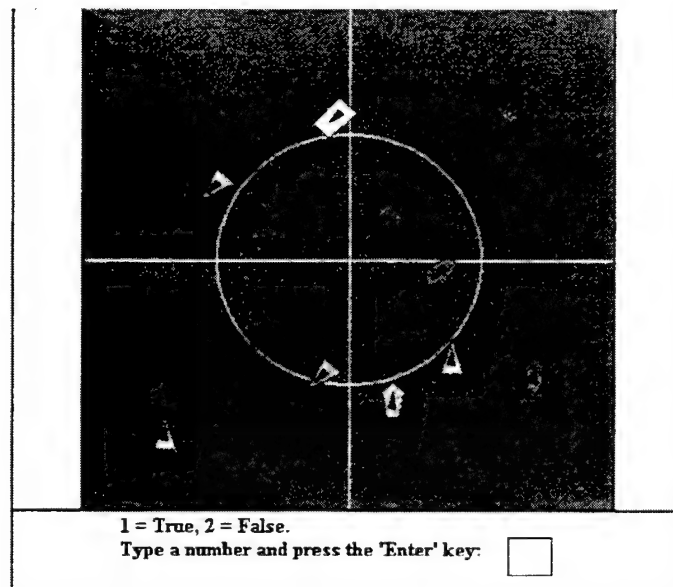


Figure 8. Tactical Display.

## PROCEDURES

All subjects at ACU-5 and ACU-4 were tested at their units in November and December 1995. The purpose for the project, and a brief description of each test was given, and appropriate informed consent procedures reviewed. Performance measures on the test were used as the predictors, and instructor ratings of the navigators were used as the criterion data. All instructors were asked to rate individuals on their abilities as a navigator on a scale 1-10, with 1 being optimal. A preliminary predictive model was generated from this concurrent validation sample and screening of navigator student candidates began in May 1996. For those individuals screened on the system, criterion data (training outcome) were collected for predictive validation of the system and possible modification of the model.

# RESULTS

## CONSTRUCTION OF SCORES

This initial section provides documentation on how the eight scores, $S_i$, were formed. Four of the scores, 1) Percentage correct on CVT, 2) Reaction Time (RT) to answers on CVT, 3) RT to questions on CVT and, 4) Dichotic Listening Task were not constructed from any more basic variables. The other four scores, 5) Absolute Difference Task, 6) Dual Task (Stick with DLT), 7) Manikin, and 8) Time Estimation Task were each constructed from two underlying basic variables related to the constructed score. All eight scores were brought into a common metric by a process similar to forming a standardized score. That is, a mean was subtracted from each raw score and then divided by a standard deviation. These means and standard deviations came from the scores obtained by the 58 LCAC fleet navigators in the aforementioned concurrent validation study. The means and standard deviations used in this standardizing process are listed below in Table 1.

Table 1: The means and standard deviations on each of the eight test scores as calculated from the 58 LCAC fleet navigators. These means and standard deviations were used to standardize subsequent scores as obtained from the LCAC candidates.

| Number | Test | Mean | Standard Deviation |
|--------|------|------|--------------------|
| 1 | Absolute Difference | 38.770 | 16.76 |
| 2 | Percentage Correct on CVT | 0.716 | 0.08 |
| 3 | RT to CVT Questions | 11.202 | 3.15 |
| 4 | RT to CVT Answers | 8.094 | 1.70 |
| 5 | Dichotic Listening Task | 102.121 | 5.04 |
| 6 | Manikin | 51.678 | 20.77 |
| 7 | Dual Task (Stick with DLT) | 19.234 | 3.36 |
| 8 | Time Estimation Task | 3.330 | 0.22 |

The absolute difference score was formed by taking the number correct minus the number incorrect as averaged over two sessions. The Dual Task score was formed by taking the DLT score and dividing by the logarithm to the base 10 of the tracking error score using the stick. The Manikin score, like the Absolute Difference score, was number correct minus number incorrect averaged over two sessions. The Time Estimation score was the average of the logarithm to the base 10 of the tracking error portion of the test over two sessions.

For three of these scores, 1) RT to answers on CVT, 2) RT to questions on CVT, and 3) Time Estimation Task, the standardized score as computed above was made negative if positive and likewise made positive if negative. The reason for this flip-flop is because lower RT and lower tracking error represent better performance while higher RT and higher tracking error represent worse performance.

## THE BAYESIAN FRAMEWORK FOR THE PREDICTION ALGORITHM

The algorithm encoded in the system software predicts whether a candidate for the LCAC navigator position will pass or fail training. The algorithm compares the distance of a composite score earned by a candidate to the mean composite score for a group of trainees who have already passed training and to the mean composite score for a group of trainees who have already failed training. If the candidate's composite score is closer to the pass group, then the candidate is predicted to pass. Otherwise, the candidate's score is closer to the mean of the fail group and is therefore predicted to fail. The mathematical derivation to arrive at this algorithm and a couple of numerical examples are provided to show how it works in practice.

A result from Bayesian statistical decision theory (Blower, 1996) states that if the likelihood ratio is greater than or equal to some number, $\beta$, then a pass is predicted. If the likelihood ratio is less than $\beta$, then a fail is predicted. In symbols,

> If $\mathcal{L}(x) \geq \beta$, predict PASS
>
> Otherwise, predict FAIL

where $\mathcal{L}(x)$, the likelihood ratio, is defined as

$$\mathcal{L}(x) \equiv \frac{P(\text{Composite Score}|\text{Pass})}{P(\text{Composite Score}|\text{Fail})} \tag{1}$$

$\beta$ is determined by the ratio of the prior probabilities of pass and fail and by the relative costs of making correct and incorrect decisions. In this situation of equal prior probabilities and symmetrical costs for right and wrong decisions, $\beta$ is equal to 1. The prediction algorithm now reads as

> If $\mathcal{L}(x) \geq 1$, predict PASS
>
> Otherwise, predict FAIL

The only computation that remains is the determination of the likelihood ratio, $\mathcal{L}(x)$. The composite score is derived from a discriminant analysis. The discriminant analysis forms a weighted linear combination of eight variables from the test battery called the composite score. The separation between the mean of the composite scores of those that passed and the mean of the composite scores of those that failed is made as wide as possible while, at the same time, the spread of composite scores within each of the two groups is made as narrow as possible. These composite scores are generally assumed to be normally distributed and by construction to have a standard deviation of 1. Therefore, the probability density function (pdf) for a composite score, $x$, is a normal pdf,

$$P(\text{composite score}) = \frac{1}{\sqrt{2\pi}\sigma} \exp\left\{ -\frac{1}{2}\left(\frac{x-\mu}{\sigma}\right)^2 \right\} \tag{2}$$

For the pass group, this is expressed as

$$P(\text{composite score}|\text{Pass}) = \frac{1}{\sqrt{2\pi}} \exp\left\{ -\frac{1}{2}(x-\mu_{Pass})^2 \right\} \tag{3}$$

and for the fail group as

$$P(\text{composite score}|\text{Fail}) = \frac{1}{\sqrt{2\pi}} \exp\left\{ -\frac{1}{2}(x-\mu_{Fail})^2 \right\} \tag{4}$$

since $\sigma_{Pass} = \sigma_{Fail} = 1$.

Forming the likelihood ratio of the composite scores results in

$$\mathcal{L}(x) = \frac{P(\text{Composite Score}|\text{Pass})}{P(\text{Composite Score}|\text{Fail})} \tag{5}$$

$$= \frac{\frac{1}{\sqrt{2\pi}} \exp\{-\frac{1}{2}(x-\mu_{Pass})^2\}}{\frac{1}{\sqrt{2\pi}} \exp\{-\frac{1}{2}(x-\mu_{Fail})^2\}} \tag{6}$$

$$= \exp\left\{ -\frac{1}{2}(x-\mu_{Pass})^2 + \frac{1}{2}(x-\mu_{Fail})^2 \right\} \tag{7}$$

$$= \exp\left\{ \frac{(x-\mu_{Fail})^2 - (x-\mu_{Pass})^2}{2} \right\} \tag{8}$$

8

The exponential format can be eliminated by taking the natural logarithm of both sides of the prediction algorithm.

$$\ln \mathcal{L}(x) \geq \ln \beta \tag{9}$$

$$\frac{(x - \mu_{Fail})^2 - (x - \mu_{Pass})^2}{2} \geq \ln 1 \tag{10}$$

$$(x - \mu_{Fail})^2 - (x - \mu_{Pass})^2 \geq 2 \ln 1 \tag{11}$$

$$(x - \mu_{Fail})^2 - (x - \mu_{Pass})^2 \geq 0 \tag{12}$$

$$(x - \mu_{Fail})^2 \geq (x - \mu_{Pass})^2 \tag{13}$$

The negative of the squared terms could be taken as well and, finally, since Equation (13) just represents a distance along a line, we can dispense with the squaring and take the absolute value of the two terms as the final form of the algorithm.

> If $| \mu_{Fail} - x | \geq | \mu_{Pass} - x |$, then predict PASS
> Otherwise, predict FAIL

This illustrates the remark in the opening paragraph that a simple distance calculation to the mean of the two groups is all that is needed to determine the proper classification.

## THE REVISED ALGORITHM

This section describes the revised prediction algorithm put in place as of December 1997. It reflects the data from 13 subjects tested at NAMRL from May 1996 to November 1997 for which training outcomes were available and 5 subjects tested at ACU-4 and ACU-5 in October and December of 1995. These 18 subjects all entered LCAC navigator training, and criterion data as to whether they subsequently passed or failed training had been recorded. Five additional subjects were added to help determine the revised algorithm; these were the predicted failures from the original algorithm, which we assumed would have been actual failures had they entered training. Thus a total of 23 subjects formed the basis for the revised algorithm.

The prediction algorithm described in this section will be used to screen LCAC navigator candidates commencing in December 1997 to some date in the near future when the algorithm will be revised as more candidates are tested and more training outcomes received. The original algorithm used prior to this revised algorithm is described in the next section. This original algorithm screened the 18 subjects mentioned above plus an additional 12 candidates who are either currently in training or awaiting training.

A numerical example of the prediction algorithm contained in the last outlined box follows. The coefficients for the composite score, $x$, are found by discriminant analysis. The coefficients for each of the eight tests are listed in Table 2. These are unstandardized coefficients, $c_i$, which multiply the score, $S_i$, obtained by a candidate on each of the eight tests. The composite score is computed then as,

$$x = \sum_{i=1}^{8} c_i S_i + \text{Constant} \tag{14}$$

For example, subject 364 obtained the following scores as listed in Table 3. The mean of the composite scores for the FAIL group was $\mu_{Fail} = -1.761$, and the mean of the composite scores for the PASS group was $\mu_{Pass} = 1.614$. It is obvious that this candidate's score is closer to the mean of the PASS Group and, therefore, would be classified as a predicted PASS. Formally, the prediction algorithm works out as,

$$| \mu_{Fail} - 1.897 | \geq | \mu_{Pass} - 1.897 |$$

9

Table 2: The coefficients, $c_i$, of the composite score for the revised algorithm as determined by discriminant analysis.

| Number | Test | Coefficient |
|--------|------|-------------|
| 1 | Absolute Difference | 2.031 |
| 2 | Percentage Correct on CVT | 0.614 |
| 3 | RT to CVT Questions | 0.138 |
| 4 | RT to CVT Answers | −0.143 |
| 5 | Dichotic Listening Task | −0.449 |
| 6 | Manikin | −0.024 |
| 7 | Multi-Task Stick with DLT | −0.124 |
| 8 | Time Estimation Task | 0.709 |
| 9 | Constant | −1.089 |

Table 3: The calculation of the composite score for an LCAC navigator candidate who is a predicted PASS.

| Number | Test | Score | Coefficient | Multiplication |
|--------|------|-------|-------------|----------------|
| 1 | Absolute Difference | 0.5507 | 2.031 | 1.118 |
| 2 | Percentage Correct on CVT | 1.6750 | 0.614 | 1.028 |
| 3 | RT to CVT Questions | 0.5530 | 0.138 | 0.076 |
| 4 | RT to CVT Answers | −1.0447 | −0.143 | 0.149 |
| 5 | Dichotic Listening Task | 1.1665 | −0.449 | −0.524 |
| 6 | Manikin | −0.6346 | −0.024 | 0.015 |
| 7 | Multi-Task Stick with DLT | 1.1678 | −0.124 | −0.145 |
| 8 | Time Estimation Task | 1.7861 | 0.709 | 1.266 |
| 9 | Constant | 1.0000 | −1.089 | −1.089 |
| | | $\sum c_i S_i + \text{Constant} =$ | | 1.897 |

$$|-1.761 - 1.897| \geq |1.614 - 1.897|$$

$$3.658 \geq .283$$

Since this is true, the algorithm predicts PASS.

An example of a predicted FAIL according to the revised algorithm is subject 365 with scores as listed in Table 4. Again, it is immediately clear that this composite score is closer to the mean of the FAIL group than to the mean of the PASS group and thus would be a predicted FAIL. The formal computation as dictated by the prediction algorithm to reach a similar conclusion would be

$$|\mu_{Fail} - (-3.325)| \geq |\mu_{Pass} - (-3.325)|$$

$$|-1.761 + 3.325| \geq |1.614 + 3.325|$$

$$1.564 \geq 4.939$$

Since this not true, the algorithm predicts a FAIL.

10

Table 4: The calculation of the composite score for an LCAC navigator candidate who is a predicted FAIL.

| Number | Test | Score | Coefficient | Multiplication |
|--------|------|-------|-------------|----------------|
| 1 | Absolute Difference | −1.0304 | 2.031 | −2.092 |
| 2 | Percentage Correct on CVT | 0.6333 | 0.614 | 0.389 |
| 3 | RT to CVT Questions | −1.4248 | 0.138 | −0.197 |
| 4 | RT to CVT Answers | −1.7212 | −0.143 | 0.246 |
| 5 | Dichotic Listening Task | 0.7696 | −0.449 | −0.346 |
| 6 | Manikin | −0.8753 | −0.024 | 0.021 |
| 7 | Multi-Task Stick with DLT | 1.0303 | −0.124 | −0.128 |
| 8 | Time Estimation Task | −0.1828 | 0.709 | −0.130 |
| 9 | Constant | 1.0000 | −1.089 | −1.089 |
| | | $\sum c_i S_i$ + Constant = | | −3.325 |

Note that the original algorithm predicted this candidate as a PASS as explained in the next section. The newly revised algorithm corrects this mistake made by the original algorithm as well as several other wrongly predicted PASSes. The 2 x 2 classification table of results for the 23 LCAC navigator candidates for which we currently possess training outcomes is shown in Table 5. The revised algorithm has only two misclassifications.

Table 5: The classification table of results for 23 candidates using the revised algorithm.

|  |  | Prediction | | |
|--|--|------------|--|--|
|  |  | PASS | FAIL | |
| Actual | PASS | 11 | 1 | 12 |
| | FAIL | 1 | 10 | 11 |
| | | 12 | 11 | 23 |

The predicted FAILs of the original algorithm are also all predicted FAILs under the revised algorithm. Because the candidates who were predicted FAILs under the original algorithm never actually entered training, it is an assumption that they would have all, in fact, failed training. Indeed, this is an assumption that we know is not entirely correct. Some of the predicted FAILs under any algorithm would have successfully passed training, but in this early development of the predictive algorithm, we will consider all predicted FAILs as actual FAILs. Later on, after more data are collected, we can develop models, where some of the predicted FAILs who had the highest probability of actually passing, could be treated as actual PASSes. These new models would average over the uncertainty surrounding these ambiguous cases.

## THE ORIGINAL ALGORITHM

Because the sponsor wanted to make the decision to admit LCAC navigator candidates into training without conducting a study where criterion data were gathered first, we had to guess at an initial model. We were not entirely in the dark, however, because a concurrent validation study had been run on LCAC navigators already in the fleet. These 58 subjects took the same battery of tests as did the LCAC candidates at their respective fleet squadrons, ACU-4 and ACU-5, in October and December of 1995. By definition, these subjects formed a distribution of composite scores from the PASS group. What was missing was a comparable set of scores from subjects who had failed training. Without a FAIL group, no discriminant analysis could be performed to find an optimal set of coefficients to form a linear composite score that best separated PASSes from FAILs.

The initial guess at a composite score was to simply weight each test equally and in a positive direction. These composite scores were plotted for the 58 fleet navigators. The mean of these composite scores for this PASS group equaled $\mu_{Pass} = 0$, with a standard deviation of $\sigma_{Pass} = .52$. To choose a cut-off score, we decided to place the cut-off score at the bottom 20% of this distribution. This resulted in a threshold score of -.375.

The calculation of the composite scores under the original algorithm are repeated for subjects 364 and 365 and shown in Tables 6 and 7, respectively. Both composite scores are above -.375 and therefore both candidates were predicted PASSes. This was an incorrect decision for subject 365 as he eventually failed training. Indeed, the original algorithm did not work very well as 5 of the 13 predicted PASSes eventually failed training.

Table 6: The calculation of the composite score under the original algorithm for an LCAC navigator candidate (#364) who is a predicted PASS.

| Number | Test | Score | Coefficient | Multiplication |
|--------|------|-------|-------------|----------------|
| 1 | Absolute Difference | 0.5507 | 0.125 | 0.069 |
| 2 | Percentage Correct on CVT | 1.6750 | 0.125 | 0.209 |
| 3 | RT to CVT Questions | 0.5530 | 0.125 | 0.069 |
| 4 | RT to CVT Answers | −1.0447 | 0.125 | −0.131 |
| 5 | Dichotic Listening Task | 1.1665 | 0.125 | 0.146 |
| 6 | Manikin | −0.6346 | 0.125 | −0.079 |
| 7 | Dual Task (Stick with DLT) | 1.1678 | 0.125 | 0.146 |
| 8 | Time Estimation Task | 1.7861 | 0.125 | 0.223 |
| | | | $\sum c_i S_i =$ | 0.6525 |

Table 7: The calculation of the composite score under the original algorithm for an LCAC navigator candidate (#365) who is a predicted PASS.

| Number | Test | Score | Coefficient | Multiplication |
|--------|------|-------|-------------|----------------|
| 1 | Absolute Difference | −1.0304 | 0.125 | −0.129 |
| 2 | Percentage Correct on CVT | 0.6333 | 0.125 | 0.079 |
| 3 | RT to CVT Questions | −1.4248 | 0.125 | −0.178 |
| 4 | RT to CVT Answers | −1.7212 | 0.125 | −0.215 |
| 5 | Dichotic Listening Task | 0.7696 | 0.125 | 0.096 |
| 6 | Manikin | −0.8753 | 0.125 | −0.109 |
| 7 | Dual Task (Stick with DLT) | 1.0303 | 0.125 | 0.129 |
| 8 | Time Estimation Task | −0.1828 | 0.125 | −0.023 |
| | | | $\sum c_i S_i =$ | −0.350 |

As mentioned previously, this algorithm was in effect to screen LCAC candidates from the beginning of testing in May 1996 until the revised algorithm went into effect in December 1997. A total of 30 LCAC candidates were screened by the original algorithm; 25 candidates were predicted PASSes under this algorithm and entered LCAC navigator training. Five candidates were rejected from entry into training because their composite scores fell below the threshold of -.375. These 5 candidates would also have been predicted FAILs under the revised algorithm.

## DISCUSSION

Our goal was to develop a computer-based selection system that was tailored specifically to the LCAC navigator position, a community that had experienced attrition rates in excess of 50%. NAMRL had successfully transitioned a previous selection system for the LCAC operators and engineer's programs using a predictive validation methodology. For this system, however, the program sponsor wanted a preliminary model for screening navigators as quickly as possible. So, based on the information gathered from a concurrent validation sample, a preliminary model was generated, and a composite score was computed from each of the subtests. The decision was then made by the sponsor to set the cut-off score at the 20th percentile of the concurrent validation sample.

Thirty LCAC navigator candidates have been screened by the preliminary algorithm. Five of these were predicted failures and therefore did not enter training. Of the remaining 25 who were predicted passes, 13 have have completed training, and we are awaiting the training outcome of the remaining 12. The 23 candidates represented in Table 5 consist of the 13 candidates who have completed training, 5 predicted failures for whom we assumed actual failure, and 5 students tested at ACU-4 and ACU-5. Of the 13 candidates who completed training and were screened by the original algorithm as predicted passes, 5 have failed training. This prompted us to seek an early modification to the original predicition algorithm.

This report presents the first modification of the preliminary model using a predictive validation sample. The new model, which should improve the ability of the system to screen those applicants most likely to succeed in training, accurately predicts the training outcome for 98% of the cases/applicants. The major difference between these models is the increased weightings for some of the subtests. Overall, tests that included a psychomotor tracking (stick) component were not as predictive of eventual success in navigator training as the other tests. The AD, CVT, and TET are most heavily weighted in the new algorithm, with better performance -- measured by the percentage of correct responses for the AD and CVT task and pixel distance from target for the TET -- being associated with a higher probability of success in training. These findings are not that surprising given that the primary tasks of a navigator involve visual recognition, time/course corrections and computations, as well as time/distance observations based upon images on their CRTs. These tasks match up relatively well with the basic skills measured by each of these subtests, however, the findings for two of the subtests, the DLT and Manikin do not make intuitive sense. These tests have been found to be predictive of other criterion in this laboratory, both within the LCAC and aviation communities (Blower & Dolgin, 1991; Dolgin, et al., 1992). However, in the current study, both tests have relatively smaller weightings in the final model than the other variables, and the direction of the relationships (better performance predicting training failure) are opposite to those that were expected. As greater numbers of applicants are screened using the new system model and more criterion data become available, it is possible that these unexpected relationships will stabilize, change direction or disappear entirely.

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# APPENDIX A. EXAMINER'S MANUAL FOR THE LCAC
## NAVIGATOR SELECTION SYSTEM

## GETTING THE SYSTEM READY

1.  Turn on the computer.

2.  It should automatically start in Windows. However, if it the C:\ prompt appears on the screen, type WIN and hit enter.

## TO CALIBRATE THE JOYSTICKS

3.  Once in windows, double click on the icon titled "MAIN."

4.  Then double click on "CONTROL PANEL."

5.  Then double click on "JOYSTICKS."

6.  On the screen you will see that the button next to the label "JOYSTICK 1" should be highlighted. "Joystick 1" is the joystick that is in the center of the system as you are sitting facing the monitor. It moves in all four directions (up, down, left, right). Click on the button on the screen that says "CALIBRATE."

7.  To calibrate Joystick 1 follow the directions that are given on the screen. First move Joystick 1 to the upper left position and click the trigger button.

8.  Now move Joystick 1 to the lower left position and again click on the trigger button.

9.  Now move it to the lower right position and click the trigger button.

10. Finally, move it to the upper right position and click the trigger button.

11. Now check that the calibration is centered. Do this by clicking the button that says "TEST". The cross hair should be centered on the screen. If it is not centered use the black dials located on the pad of Joystick 1 to center the cross hair as much as possible. You may not be able to get it perfectly centered, but get it as close as possible. When you are done centering the cross hair, click the "DONE" button. If had to mess with the dials, then it is **VERY IMPORTANT** that you **RE-CALIBRATE** the joystick again. (Start back at # 6.) If you didn't move the dials, then proceed with # 12.

12. Once you have completed the calibration of Joystick 1, you will now have the option to choose Joystick 2. Click the button to the right of this title (on the screen).

13. Joystick 2 is a combination of the stick (located to your left side as you face the computer) and the rudder pedals (located at your feet).

14. The stick moves up and down, while the rudder pedals control left and right motion.

15. Now choose to "CALIBRATE."

16. Again, follow the instruction provided on the screen. First move the stick in the up position and the move the rudder pedal into the left position. Do this by moving your left leg forward. Once this is done, click the trigger button on the stick.

17. Leaving the rudder pedals in the left position, pull the stick into the down position and click the trigger button.

18. Now, leaving the stick in the down position, move the rudder pedals into the right position. This done by moving your right leg all the way up. Once this is done, click the trigger button.

19. Finally, leaving the rudder pedals in the right position, move the stick into the up position and click the trigger button.

20. Now check that the calibration is centered. Do this by clicking the button that says "TEST." The cross hair should be centered on the screen. If not, check two different things. First, it is off center in the up and down position? If yes, then move the black dial on Joystick 2 until the cross hair is centered. Second, if it is off center in the left and right position then you have to rotate the dial located on the rudder pedals. This dial is found in between the two pedals. It looks more like a cog wheel. You have to pull up on it, then rotate it until the cross hair is centered. Once you get it as close to center as you can, you have to push it back down into place again.* You may not be able to get it perfectly centered, but get it as close as possible. When you have finished with the test, click the "DONE" button. If you had to adjust the dials, then it is **VERY IMPORTANT** that you **RECALIBRATE** the joystick again. (Start back at # 12.) If you didn't move the dials, then proceed with # 21.

\* It is also important that you ALWAYS make sure that the cogs are flush with one another, or you can lose calibration during testing.

After the system is calibrated, click the OK button and the computer will save the calibrations.

## TO START TESTING

1. You should still be in the Windows screen.

2. To start the LCAC test, double click on the icon that reads "LCAC NAVIGATOR."

3. The next screen will be a picture of the LCAC with the following options: "TEST", "DEMO", and "EXIT."

## INSTRUCTIONS TO EXAMINEES:

**Say:**

*"This is a test that measures eye-hand coordination, cognitive abilities, spatial abilities, and listening skills."*

Show them the system and **say:**

*"This is the station that you will be working at. You will only be using the joystick in the center, the headphones, and the number keypad. When you hold the joystick, hold it like you would normally hold a joystick with your index finger on the trigger button. For most of the tests you will not be using this button; however, we have found that it helps you to stabilize your wrist and gives you more control over the object. This joystick moves in all four directions.*

*Notice the black dials on the gray part of the joystick. It is important that throughout testing you Do Not play with these dials in any fashion. They are part of the calibration and by changing them, you can damage your scores."*

Show them the headphones and then **say:**

*"Look at these headphones. You will only be using these headphones for two of the subtests, so you will not need to wear them throughout the entire test. The computer will tell you when you need to put them on. Notice that one side is labeled left and one side is labeled right. It is important for you to put the left on the left ear and the right on the right ear. The reason for this is that you will be doing a dichotic listening test. In this test, information will be presented to you through the headphones. Each ear will receive different information in the form of numbers and letters. The computer will tell which ear you should listen to. For instance, the computer will say, Test 1, Left Ear. At this point you need to ignore the information coming into the right ear and input **only the numbers** you hear coming into the left ear. You need to enter these numbers into the keypad as you hear them. **Do Not** try to memorize the numbers and then enter them. You will not get proper credit for your responses. The first time that you use the headphones, it will be just these responses alone that you will be making.. You may be tempted to use your right hand to enter the numbers. However, you will need to use your left hand because the next time you use the headphones you will be using your right hand to control the stick and keep an object centered on the screen. So, use your left hand when entering the numbers into the keypad."*

*"You will get a practice session before some of the subtests begin. For those that you do not, I am going to explain them to you and then demo them for you."*

You will only demo three subtests: The Absolute Difference Task, the Manikin, and the Time Estimation Task.

At this time, sit down at the test station and click on the icon that says "DEMO." Change the demo time to .5. Do that by moving the mouse to the area that says "DURATION," highlight the "1," and type in the appropriate time, ".5."

*"The first test that I'm going to show you is called the Absolute Difference Test. A series of numbers are presented to you on the screen one at a time. You are to take the absolute difference between the previous number presented and the current number on the screen. For instance, say that the # 8 is the first number presented, then the # 7. You should enter the absolute difference between the 8 and the 7 into the keypad, which is 1. Once you do that, a new number will appear. Let's say it is the # 9. Now you will take the absolute difference between the # 7, which was the previous number, and the # 9. You then need to enter that number, which is 2, into the keypad.*

At this point, you should start the demonstration. Click on the icon labeled "ABSOLUTE DIFFERENCE." You need to explain to the subjects that when the instructions say hit the #1 key that it is only to start the program and has no other significance.

Once you have completed this demo, move on to the next subtest.

**Say:**

*"The next test that I'm going to show is called the Manikin. You will see the image of a sailor. In one hand he is holding a green circle, in the other hand he is holding a red square. Your task is to determine which hand is holding the **red square**. It is important that you remember this because once the test begins, you will not be prompted with that information again. The sailor can be in four different positions. He can be right-side up and facing you, right-side up and backwards, upside-down and facing you, or upside-down and backwards. You will be using the # 1 key to choose the left hand and the # 2 key to choose the right hand."*

Start the demo and as you choose which hand is holding the square, say aloud the proper hand. Ask them if they have any questions. Then move to the next subtest.

**Say:**

A-3

*"The next test is called the Time Estimation Task. This is a dual tasking test, which simply means you will be doing two things at once. The first thing that you will be doing is controlling a cross hair at the bottom of the screen using the joystick in front of you. At the top of the screen, an airplane will appear on the left hand side, only staying visible for about 2 seconds. It will then disappear into a cloud. On the right hand side of the screen is a missile. The object of the task is to estimate at what point you think the airplane will be over the missile. At that point you will use the trigger button to fire a missile. Once you fire, a number will appear. A positive number means that you fired too soon and a negative number means that you fired too late. A zero means that you hit it perfectly. The speed of the airplane will vary between trails, but will remain constant within a trial. So, if initially it is going at a slow speed, it will maintain that same slow speed throughout that trial. Again, remember that the whole time you are doing this, you should be controlling the cross hair at the bottom of the screen."*

At this point, demo the subtest while repeating the task instructions.

When you have finished going through all the demos, it is time to start the test. Exit the demo mode by clicking on the "EXIT" button. You should be at the main screen that had the initial three options: "TEST," "DEMO," "EXIT." Click on the "TEST" button. At this point, an instruction screen will appear.

**Say:**

*"You are now ready to begin the test. It will take you approximately 1 hour to take this test. The computer will not move into the next subtest or to another screen without you physically doing something, either by pressing the page down/page up or the enter key. Therefore, if you need to take a break (use the restroom or get some water), go ahead. If you have any questions about any instructions throughout the test please come and ask me before you begin the test. Once you start a test I* **cannot** *stop it. Once you get started, the computer will prompt you for a Subject ID #, enter the number that was assigned to you earlier. Do you have any questions? Go ahead and begin the test."*

At this point, leave the individual to him- or herself.


**ADMINSTERING THE CVT**

Once the individual has completed the psychomotor portion of the test, you will need to administer the "Complex Visual Task" test.

You will be giving the demonstration on the psychomotor test station and the actual test will be given on Test Station # 3 (This is in the corner, next to the psychomotor station.) Double click on the icon "CVT."

**Say:**

*"This test is called the Complex Visual Task. There are 60 questions and it will take you about 30 minutes to complete. In this test you will be presented with a series questions which will be displayed on the screen one at a time. After each individual question, you will be shown a graphic based on that question. You need to examine the graphic and determine the correct answer. Enter your answer using the number keypad and then hitting the enter key. Once you hit enter, you will not be able to change your answer. The computer will provide you feedback as to how you did and what the correct answer was."*

At this time begin the demo. You should be at the CVT screen. You will be given two options, "TAKE TEST" or "EXIT." Choose "TAKE TEST" and enter a bogus Subject ID #.

Go past the instructions, **Say:**

*"I am not going to go through the instruction screens verbatim. When you sit down to take the test, you have all the*

*time you need to take to read through the instructions."*

Show them the screen that indicates the center of the circle is the red dot. Say:

*"You may be asked a questions that says, How many objects are going through the center of the circle? That means any object that if it was in motion would pass through this red dot."*

Show them the screen that demonstrates North, South, East, West. Point this screen out to them.

Flip through the next few screens, briefly summarizing what is on them. **Say:**

*"The objects on the sides come in three sizes: large, medium, and small and in three colors: red, green, and white."*

Show them the first example. Read the question and then continue.

Read the second example and continue.

Finally, read the third example and then continue on to the next screen.

Say:

*"Some of the questions will require a true or false answer. Use the keypad to enter 1 if the answer of True and 2 if the answer is False. Once you make your response, you must hit the Enter key. Some questions will require to make a number response. If the correct answer requires a two-digit number, like 12, press the 1 key and 2 key, then hit enter. You will need to remember that the different shapes represent different objects. That information will only be given in the instructions. Try complete the test as fast as you can, but be as accurate as possible. Do you have any questions? Once you begin the test itself, I cannot answer any of your questions."*

At this point, sit the individual down at the test station to begin the test. You will need to set up the test on this computer.

1. Turn on the computer.

2. It should be in Windows, if not type WIN at the C:\ on the screen.

3. Once in Windows, double click on the icon "TEST."

4. Now double click on "CVT."

   5. You should be at the CVT screen. You will be given two options, "TAKE TEST" or "EXIT." Choose "TAKE TEST."

   1.     The subject needs to enter the same Subject ID # that was used on the psychomotor test.

## BACKING UP DATA

1. Insert a disk into the A: drive.

2. In the Windows screen, double click "MAIN."

3. Double click on "FILE MANAGER."

4.  Now scroll through the directories until you find LNAV directory.

5.  Click on this directory. You should now see the directory SCORES.

6.  Click on the SCORES directory. You will now see all the subjects' files.

7.  Scroll through the files until you find the files for that day's testing.

8.  Select the file that you want to copy by clicking the file once.

    9.  Now hit the F8 key. It will ask you where you want to copy the file. Type **A:** then hit enter.

10. Once you have copied all the appropriate files, exit the File Manager.

11. In the menu go into File, then Exit.

*** To back up the CVT data, follow the same procedures as up. Look for the CVT directory.

## TROUBLE SHOOTING

If the program should lose calibration. Do the following.

    1.  Restart the computer. Either by turning it off and then on again. Or by hitting the "Reset" button on the computer.

    2.  Go to **Calibrating the Joysticks** and follow the steps outlined in that section.

If the computer just freezes up. Do the following.

    1.  Restart the computer. Either by turning it off and then on again. Or by hitting the "Reset" button on the computer.

    2.  Go to **Calibrating the Joysticks** and follow the steps outlined in that section.

## PICKING UP WHERE THE INDIVIDUAL LEFT OFF

Once you have re-calibrated the joysticks, you need to find out the last subtest that the individual completed. To find out, do the following steps.

1.  You should still be in Windows. Double click on the icon titled "MAIN."

2.  Then double click on "FILE MANAGER."

3.  Now find the LNAV directory and double click on it.

4.  Once in the LNAV directory, double click on the SCORES directory.

    5.  Scroll through the directory until you find the subject's file. (This should be his/her subject id #.)

6.  Highlight this file and then move the cursor to the menu and click on "FILE."

7.  In the File menu, click on "RUN."

8.   The file name will appear and in front of it type WRITE (leave a space between it and the file name).  Hit Enter.

9.   The computer will ask you if you want to convert the file.  Say NO.

10.  The file that has been selected will then be open.  Scroll through the file to see which subtest is the last one completed.

11.  Each test will have a Test ID #, write the Test ID # for the last completed subtest.

   1.          Once you have done this, exit the file.  It may ask you to save changes.  Say NO.

## TO EDIT THE TEST FILE

13.  You should still be in the LNAV directory.

14.  Find the "LNAV.CFG" file.

15.  Open this file as in steps 6-9.

16.  Once the file is open, go to the file menu and select SAVE AS.

17.  Change the title to "SUBJECT ID #.CFG."

18.  Once you have done this it is time to edit the file.

19.  Delete the tests that have already been taken.  For instance, if the person got through TEST ID 3, then you delete the first 3 tests.

20.  Once you have modified the file, save the changes and exit.

21.  Open the "LNAV.EXE" file by double clicking on it.

22.  Open "ADMIN."  Here you will see a list of directories.

23.  You now need to edit the Test Script File by replacing the "LNAV.CFG" file, with the new file that was created.  This is the "SUBJECT ID #.CFG" file.

24.  Click "SAVE" and exit.

25.  Run the test using the same Subject ID #.  The scores will be appended to the existing file.

**\*\*\*\* IT IS VERY IMPORTANT THAT WHEN THIS PERSON COMPLETES TESTING THAT YOU RE-ENTER THE ADMINISTRATION DIRECTORIES AND CHANGE THE TEST SCRIPT FILE BACK TO "LNAV.CFG".  REMEMBER TO SAVE THE CHANGES \*\*\*\*\***

# REPORT DOCUMENTATION PAGE

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**13. ABSTRACT** (Maximum 200 words)
The LCAC is an amphibious hovercraft that can ride on a cushion of air across land or sea. Its control features are similar to a helicopter and it is designed to transport weapons, cargo, equipment and combat personnel. In the 1980s, the LCAC community was experiencing a high attrition rate, partially due to the absence of any valid selection mechanisms for crewmembers. The Naval Aerospace Medical Research Laboratory (NAMRL) developed a selection system for the LCAC operators and engineers and the system was transitioned to the Naval Operational Medicine Institute (NOMI) in 1992. Similar attrition problems were seen in the Navigator community and in FY 94-95 NAMRL was again tasked with developing a selection system. Concurrent validation of the system was done using 58 LCAC navigators. The preliminary predictive model was generated and the cut-off score derived from the sponsor's operational manpower needs. To date, 30 candidates have been screened with 25 being recommended for training. Thirteen of these candidates have entered training and completed the full 22 week syllabus. Five of the thirteen recommended candidates attrited during training, with multi-tasking as the main reason sited. The system is still being evaluated to (1) possibly include more multi-tasking tests, (2) modify the predictive algorithm, and/or (3) raise the cut-off score to further reduce the attrition rates.

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